Back to Basics

An Introduction to MQTT

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Based out of Chicago, Mary is a Java Champion and President and Executive Board Member of the Chicago Java Users Group (CJUG). She is also the co-organizer for several meetup groups such as, the *Data, Cloud and AI In Chicago*, *Chicago Cloud*, and *IBM Cloud Chicago*.

She has extensive experience in product and application design, development, integration, and deployment experience, and specializes in Reactive Java, Open Source, and cloud-enabled distributed systems.

AGENDA

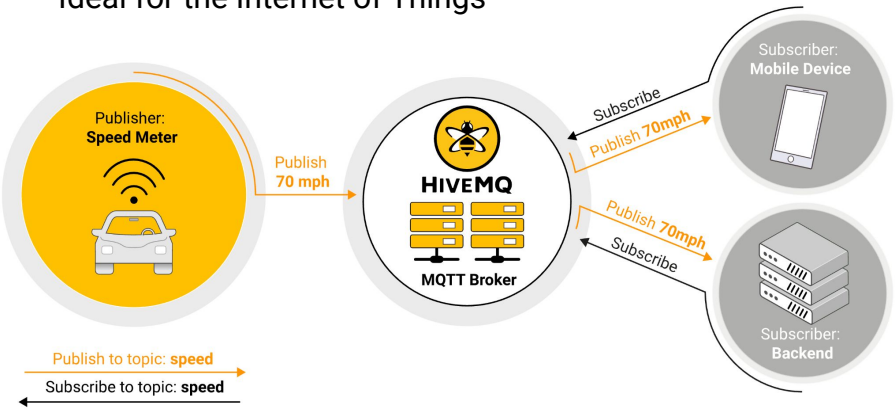
- **The IoT Stack**
- **What is MQTT?**
  - A bit of a history
  - OASIS open standard, community-driven protocol
  - MQTT 3.1.1 Features
  - MQTT 5.0 Features
- **Use Cases for MQTT**
- **Alternative Protocols for IoT**
- **Summary - Why MQTT is the top choice**
- **Demo**

From 30,000 Feet: The IoT Stack

Solutions	**Consumer** (Home, Lifestyle, Mobility, Entertainment…etc.)	**Enterprise** (ERP, Marketing, Sales, Business Ops…etc.)	**Industrial** (Manufacturing, Automotive, Logistics, Construction…etc.)
Cognitive Platform	Interactions (spoken, gestures), AI, Voice Recognition…etc.		
Analytics Platform	Services (Geospatial, Recommendations), Reports, Events, Machine Learning, Stream Processing…etc.		
Core Platform	IoT Messaging Middleware, Protocol Gateway, Data Aggregation, Data Storage/Filter		
Communication Protocols	MQTT, CoAP, AMQP, DDS, XMPP, IPv4, IPv6, 6LoWPan,Bluetooth, GSM, Modbus, BACnet		
Devices	Devices & Components: Smart Devices, Sensors & Actuators, Embedded Devices…etc.		

What is MQTT?

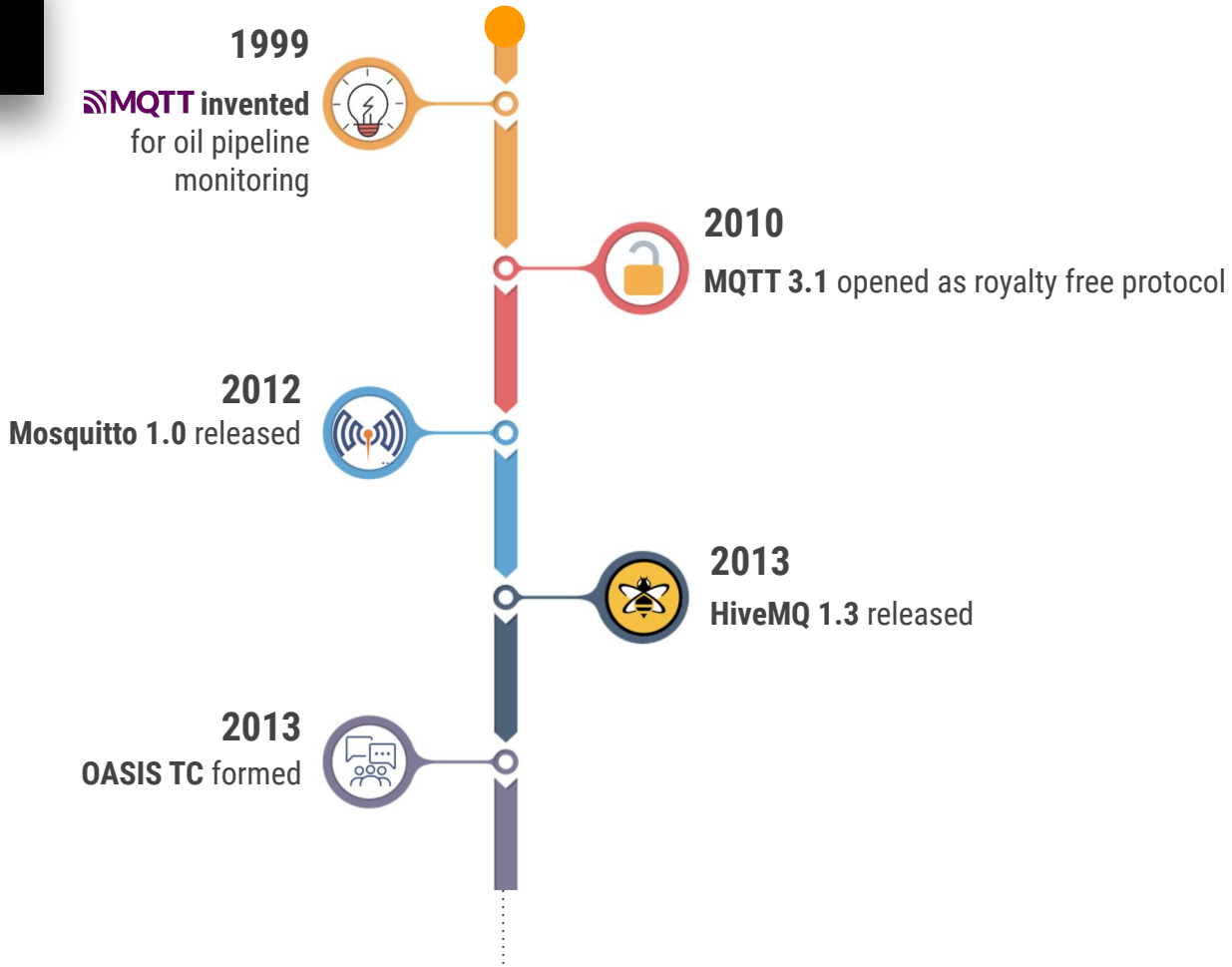
- A standard binary publish-subscribe messaging protocol designed for fast and reliable data transport between devices especially under very constrained conditions
- Constraints include unreliable network connectivity, limited bandwidth, limited battery power, and so on
- Built on top of TCP/IP
- Ideal for the Internet of Things



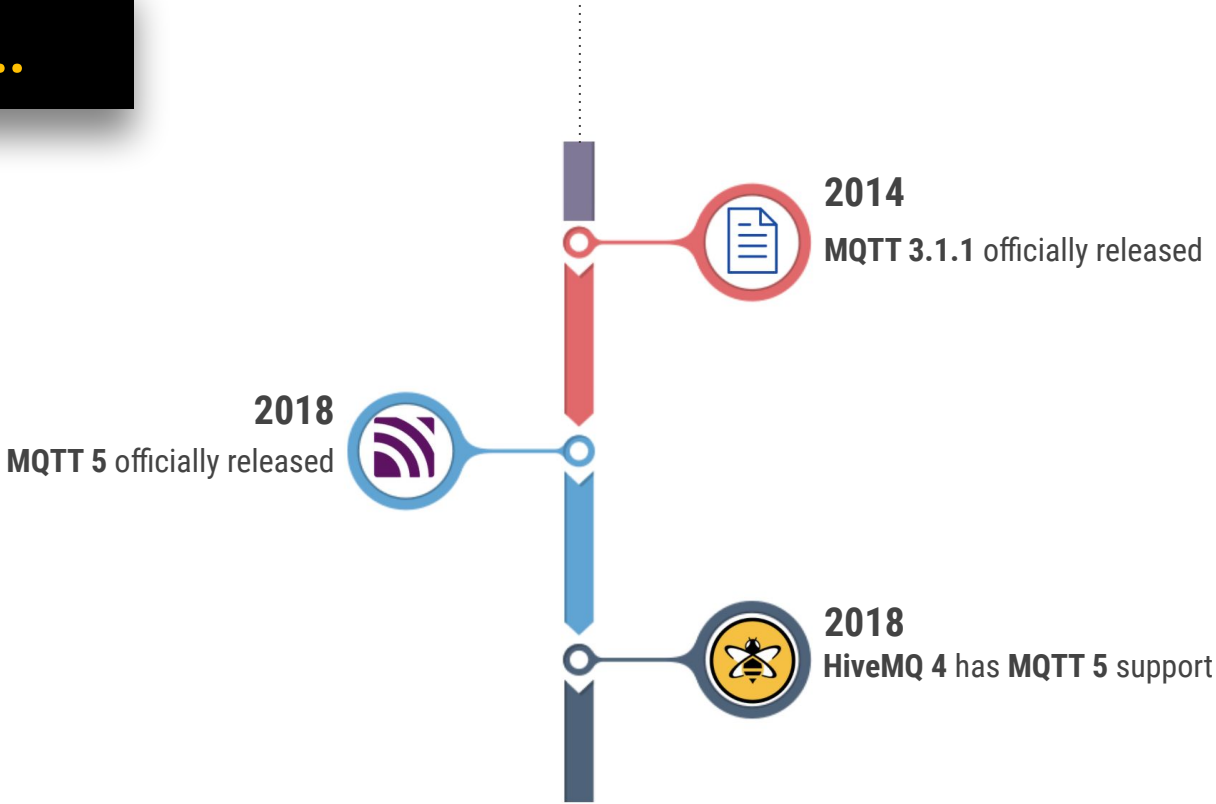
A Brief History of MQTT

- Invented in 1999 by Andy Stanford-Clark at IBM and Arlen Nipper at what was then Arcom - and now Cirrus Link
- Prompted by the need to design a protocol that could handle a very limited operating environment that can afford only minimal battery loss and minimal bandwidth to connect with oil pipelines via satellite

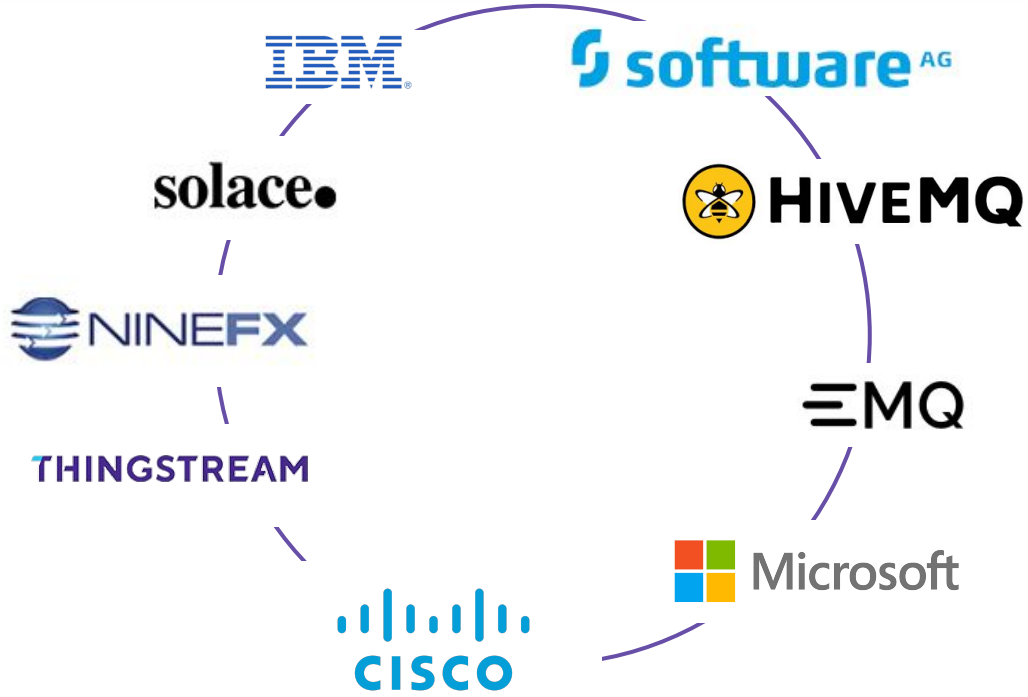
History...



History...



THE MQTT Technical Committee

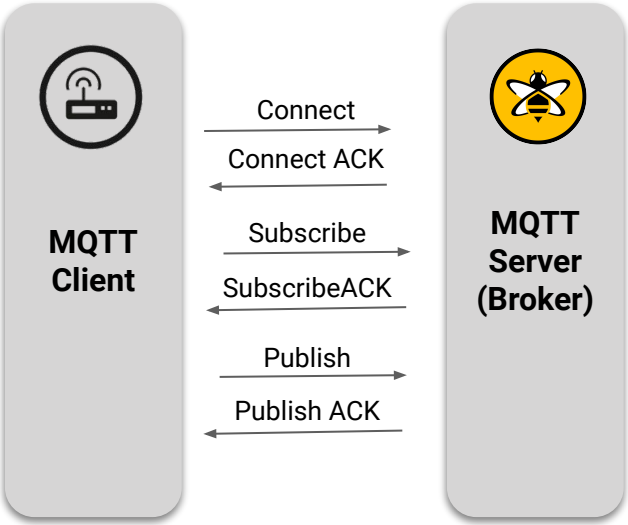


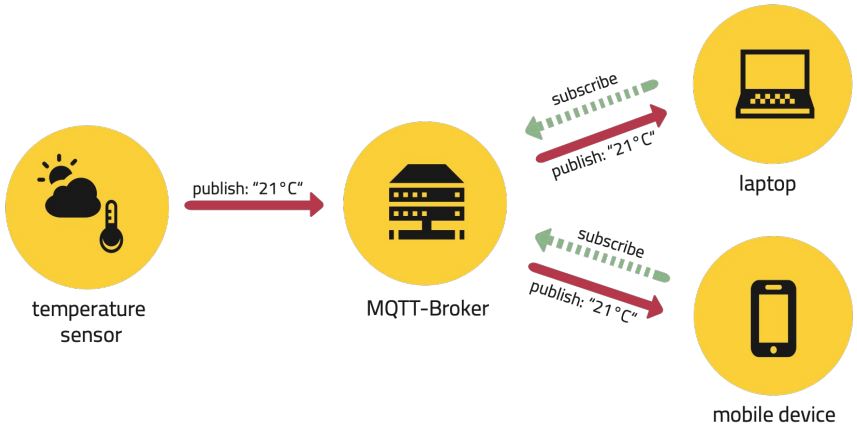
MQTT Overview

- IoT Messaging Protocol
- 3 QoS Levels
- Retained Messages
- Stateful - persistent sessions
- Binary with minimal overhead

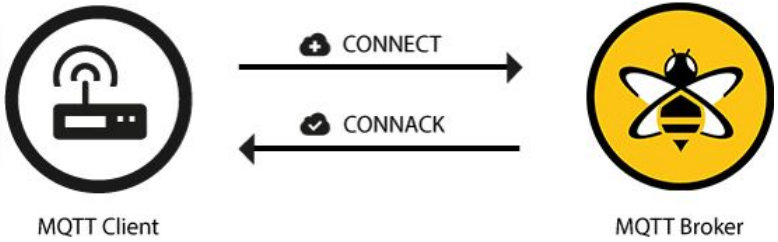
Basic Features of MQTT 3.1.1

Publish / Subscribe





CONNECT / CONACK



MQTT-Packet:

CONNECT

contains:	Example
clientId	"client-1"
cleanSession	true
username (optional)	"hans"
password (optional)	"letmein"
lastWillTopic (optional)	"/hans/will"
lastWillQos (optional)	2
lastWillMessage (optional)	"unexpected exit"
lastWillRetain (optional)	false
keepAlive	60

MQTT-Packet:

CONNACK

contains:	Example
sessionPresent	true
returnCode	0

WILL

- Client defines Will (LWT)
- Broker sends this message if this client dies
- It is a real Push
- Useful to implement on / off mechanism in a safe way
- message when Subscribing to the topic

MQTT-Packet:

CONNECT

contains:	Example
clientId	"client-1"
cleanSession	true
username (optional)	"hans"
password (optional)	"letmein"
lastWillTopic (optional)	"/hans/will"
lastWillQos (optional)	2
lastWillMessage (optional)	"unexpected exit"
keepAlive	60

Publish / Subscribe

MQTT-Packet:

PUBLISH

contains:	Example
packetId (always 0 for qos 0)	4314
topicName	"topic/1"
qos	1
retainFlag	false
payload	"temperature:32.5"
dupFlag	false

MQTT-Packet:

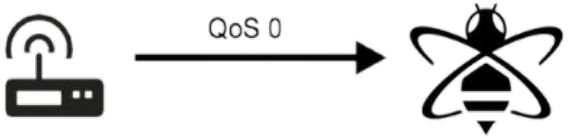
SUBSCRIBE

contains:		Example
packetId		4312
qos1	} (list of topic + qos)	1
topic1		"topic/1"
qos2	}	0
topic2		"topic/2"
...		...

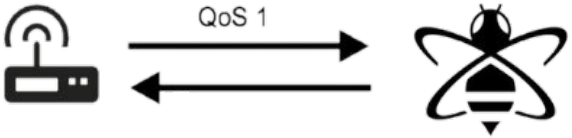
Retained Message

- Last Known “Good Value”
- Last message will be stored on broker side
- Client decides if a message is retained or not
- Future Clients get the retained message when Subscribing to the topic

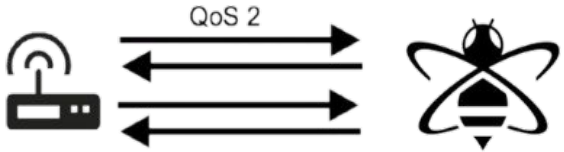
Quality of Services



QoS 0 | At most once delivery



QoS 1 | At least once delivery



QoS 2 | Exactly once delivery

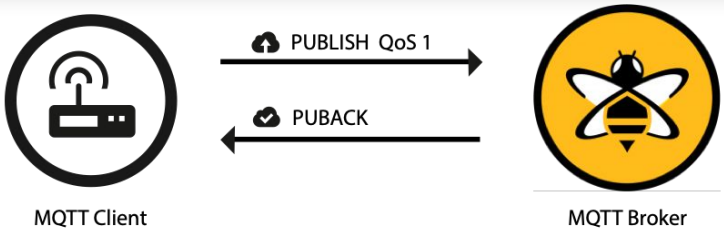
Quality of Services 0

MQTT-Packet:

PUBLISH

contains:	Example
packetId (always 0 for qos 0)	0
topicName	“topic/1“
qos	0
retainFlag	false
payload	“temperature:32.5“
dupFlag	false

Quality of Services 1



MQTT-Packet:

PUBLISH

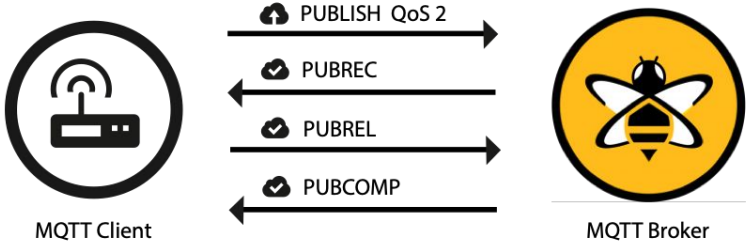
contains:	Example
packetId (always 0 for qos 0)	4314
topicName	"topic/1"
qos	1
retainFlag	false
payload	"temperature:32.5"
dupFlag	false

MQTT-Packet:

PUBACK

contains:	Example
packetId	4314

Quality of Services 2



MQTT-Packet:
PUBLISH

contains:	Example
packetId (always 0 for qos 0)	4314
topicName	"topic/1"
qos	2
retainFlag	false
payload	"temperature:32.5"
dupFlag	false

MQTT-Packet:
PUBREC

contains:	Example
packetId	4314

MQTT-Packet:
PUBREL

contains:	Example
packetId	4314

MQTT-Packet:
PUBCOMP

contains:	Example
packetId	4314

But, where is MQTT 4 ?

Hint: let's look at the CONNECT message packet detail for MQTT 3.1.1:

```
▼ MQ Telemetry Transport Protocol
  ▼ Connect Command
    ▼ 0001 0000 = Header Flags: 0x10 (Connect Command)
        0001 .... = Message Type: Connect Command (1)
        .... 0... = DUP Flag: Not set
        .... .00. = QOS Level: Fire and Forget (0)
        .... ...0 = Retain: Not set
      Msg Len: 44
      Protocol Name: MQTT
      Version: 4
    ▼ 0000 0010 = Connect Flags: 0x02
        0... .... = User Name Flag: Not set
        .0.. .... = Password Flag: Not set
        ..0. .... = Will Retain: Not set
        ...0 0... = QOS Level: Fire and Forget (0)
        .... .0.. = Will Flag: Not set
        .... ..1. = Clean Session Flag: Set
        .... ...0 = (Reserved): Not set
      Keep Alive: 60
      Client ID: 5539db7f5af54eafaa0f66ee91df3dce
```

MQTT 5

MQTT 5 - Overview

- Successor of MQTT 3.1.1
- Non-backward compatible
- First public release in January 2018, official release in March 2019
- Many new features
- Clarifications of the 3.1.1 specification

MQTT 5 - Goals

- Enhancements for scalability and large scale systems
- Improved error reporting
- Formalize common patterns including capability discovery and request response
- Extensibility mechanisms including user properties
- Performance improvements and support for small clients

NEW FEATURES

Session & Message Expiry

- Session Expiry is an optional part of the CONNECT message
- Session Expiry Interval in Seconds
- Broker expires session after the given interval as soon as the client disconnects
- Publication Expiry interval is an optional part of a PUBLISH message
- Applies to online and queued messages

User Properties

- User Defined Metadata Headers
- Can be part of most MQTT packets (CON, PUB, SUB)
- UTF-8 encoded Strings
- An unlimited number of user properties can be added

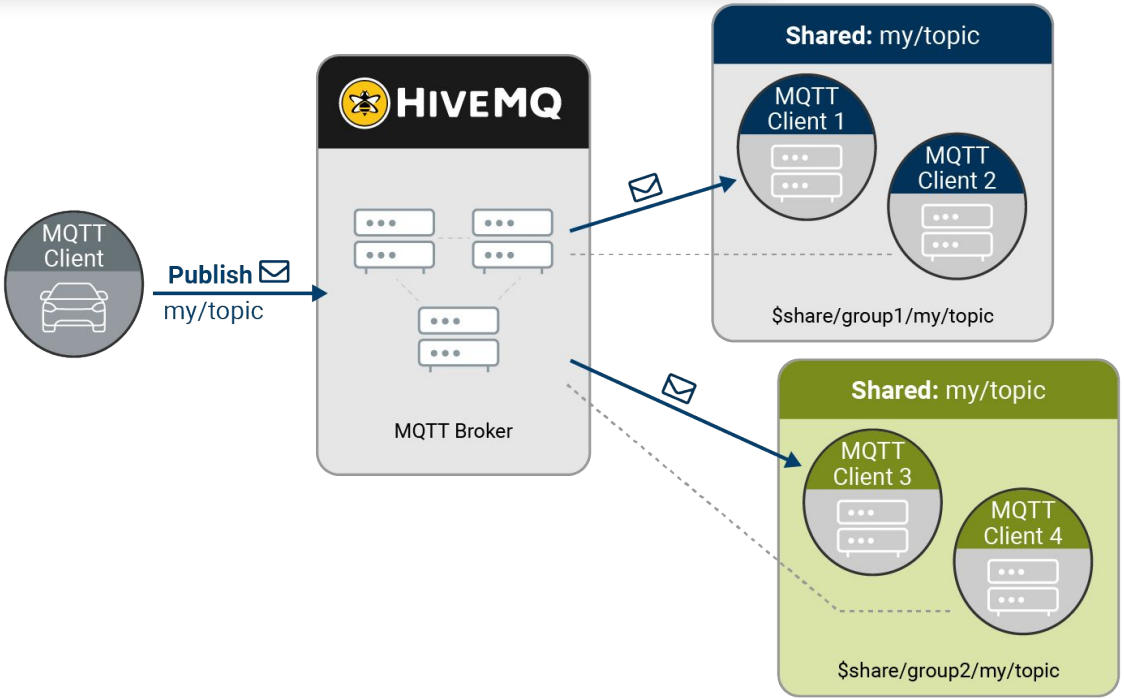
Shared Subscriptions

Special Syntax: $share/{ID}/my/topic

- Useful for scaling out backend subscribers
- Client Load Balancing. Multiple clients share the same subscription
- Also supported by HiveMQ for MQTT 3.1 and MQTT 3.1.1
- Up-/Downscaling of clients at runtime possible. Perfect for cloud native scenarios (Kubernetes, …)
- Optional feature, not supported by all vendors*

** HiveMQ fully supports all optional features, including this feature*

Shared Subscriptions

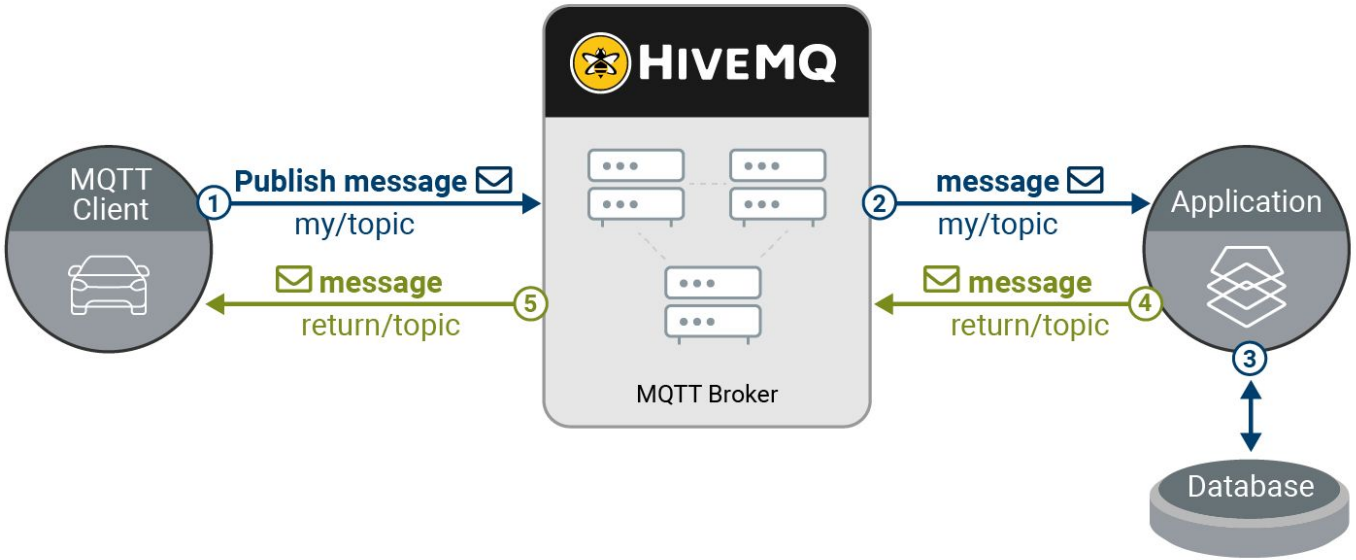


Request / Response

Pattern for “business ACKs”

- The MQTT request-response pattern is not the same as the request-response of synchronous, client-server based protocols like HTTP.
- Request as well as responses are at least Topics and can have more than one or no subscriber in MQTT.
- The Client must subscribe to a response topic prior to sending data.
- “Request Response Information” place for response topic
- “Correlation Data” header for correlation of the request and its response

Request / Response



Lightweight and Bandwidth Efficient

- Every message works as a discrete chunk of data, opaque to the broker
- MQTT Control packet structure:
  - Fixed header, Variable header, Payload
- Protocol headers are small in size:
  - 2 byte fixed header
- up to 12 bytes of additional variable header (variable size and present only when needed)

Data Agnostic

- Supports all kinds of data:
  - images
  - text in any encoding format
  - encrypted data
  - binary data

Continuous Session Awareness

- Persistent sessions
  - Broker store messages when offline
  - QoS level 1
  - Retained messages
  - Normal message with "retain" flag will be stored and sent to new subscribers to its topic
  - Last will and testaments
  - Client can specify a message to send in case it disconnects ungracefully
- Very useful in IoT especially over unreliable networks

MQTT 5

- Introduction of semantic metadata like user properties, payload indicators, or content type descriptors
- Request-response pattern
- Shared subscriptions
- Negative acknowledgments
- Message and session expiry per client
- More…

Use Cases for MQTT

- IoT
- Industrial IoT (IIoT)
- Industry 4.0
- Industry verticals:
  - Automotive
  - Logistics
  - Manufacturing
  - Energy
- Consumers:
  - Smart Home
  - Lifestyle

Alternative Protocols to MQTT

- HyperText Transport Protocol (HTTP)
- Constrained Application Protocol (CoAP)
- Advanced Messaging Queueing Protocol (AMQP)
- Object linking & embedding for Process Control - Unified Architecture (OPC-UA)
- Data Distribution Service (DDS)
- Extensible Messaging and Presence Protocol (XMPP)

Integration with Other Frameworks

- Streaming platforms: Apache Kafka
- Other MQTT Brokers: Mosquitto
- Runtimes - SpringBoot

Summary

- Simplicity - Pub/Sub - Asynchronous processing - Loosely coupled
- Lightweight
- Operating in a constrained environment
- Unreliable, high latency network
- Limited battery and other resources
- Ideal protocol for IoT use cases (other protocols such as HTTP would be too heavy)

Demo

Resources

[Get Started with MQTT]

[MQTT Essentials Series]

MQTT [MQTT at OASIS]

HIVEMQ [Evaluate HiveMQ Broker]

HIVEMQ CLOUD [Try HiveMQ Cloud]

ANY QUESTIONS?

THANK YOU

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